Geological Data for Blasting

by
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INTRODUCTION

Evolution of blast optimization at the Minntac Mine has gone through four stages. The first stage was to establish a comprehensive database detailing all layout and loading parameters in each blast. Step two involved scrutinizing the initiation system and bulk products (Eloranta, 1992). The third stage could be termed 'customer satisfaction'. Shovel speeds, crusher speeds and other pertinent downstream data and costs were added to the database (Eloranta, 1995). The fourth and current phase goes back to the basics of characterizing the blast environment.

THE BROADENING SCOPE OF BLAST OPTIMIZATION

Preconditioning of ore by blasting appears to be an increasingly important factor in blast optimization. Recent work by Nielsen and Kristiansen (1995) in Norway and by Schneider and King (1995) and by the author (1995)in the U.S.; suggest that the practical universe of blast optimization has expanded to include comminution. Lownds (1995 and 1996) has modeled blast performance based on initial fragment size, joint spacing and single particle comminution theory. For this reason, inputs for blast design should naturally include: bed thickness (initial fragment size), grindability indices and compressive strength.

The advent of drill monitoring equipment opens the door to a wealth of blast design information. Minntac already has a vast body of largely untapped data in the form of diamond drill hole logs and downhole probing with a magnetic susceptibility meter. Add to this, the feedback data from downstream performance and you have the essential components of an optimization loop. Special tactics for handling heavily jointed and massive zones require accurate locations since oversize reduction may involve drill and blast costs that can't be recouped in crushing and grinding. This paper identifies five sources of geologic input:

1. Diamond drill core
2. Drill monitoring data
3. Downhole magnetic susceptibility
4. Cross hole sonic logging
5. Video images of the face

COMPUTER PATTERN LAYOUT

Since 1991, pattern layout has been done on a computer. This was a critical step in organizing blast data. Before that patterns were hand drawn. Now a file of hole numbers and their respective coordinates is generated for each blast. Plan views, longitudinal sections and cross sections can be plotted for all holes.(Fig. 1 and 2) The sections also show information from diamond drilling; such as geologic horizon, ore grade and location of nearby diamond drill holes. The file of blasthole coordinates (some 20,000 per/year), is the basis for data organization.

DIAMOND DRILL CORE

The orebody has been delineated by diamond drilling. The drilling was done on a 300-foot by 300-foot grid. The most obvious and fundamental use of the core is to delineate ore/waste contacts and to delineate stratigraphic relationships. There are two parameters in iron ore core that are especially relevant to blasting; they include the grindability index and core length.

GRINDABILITY INDEX

The grind index test (also called the 6 minute grind) was performed on all drill core samples (see appendix for test procedure). It provides concentrator metallurgists with a measure of milling effort needed to process various ores. Grind index should receive greater attention from blast engineers in light of work done relating blast fragmentation to comminution. Grind index, along with other physical properties, establishes a starting point for the blasting/milling process.

DRILL CORE LENGTHS

Exploration drillers placed sections of drill core in a two-foot long core box for transportation and storage. These pieces came out of the core barrel in a various lengths. An unknown number of core pieces had to be broken to fit in the boxes; resulting in a shortening bias of length. However, a great deal of detail concerning bedding thickness is available for beds less than two-feet in thickness.(Duevel,1994)

To relate core lengths to size distributions in run of mine rock involves a number of assumptions. If beam bending is used as the failure mode of blasted rock, then one might assume that bed thickness represents the shortest dimension of a fragment. Casual observation of muck piles seems to support this as bedding surfaces are easy to identify in the Biwabik Iron Formation. Using an aspect ratio of 1:2:3, the two-foot long core limit translates to a maximum dimension of 6 feet. Six feet or less would account for all but a small fraction of run of mine rock. However, core pieces are broken to even shorter lengths to fill out core boxes. Because of intentionally broken core, geologic fragmentation should be augmented with other field data. The attached plot (Fig. 3) compares core lengths to resulting fragmentation measured by digital image analysis at the primary crusher. The thinner bedded areas result in better fragmentation.

PHOTOGRAPHS OF THE FACE

Photographs of pre-blast walls might serve to document the location of massive beds. The attached picture of a vertical face shows the bedding structure.(Fig. 4) This picture is a shot muckpile that is fragmented but not moved so it retains original bedding structures. Current plans are to try three commercial video systems (WipFrag, CIAS(Computer Image Analysis System) and SCV1000) to quickly digitize and measure bed thickness. Massive beds that lie in the stemming region seem to produce much of the oversize blocks.

MAGNETIC SUSCEPTIBILITY PROBE

In-situ analysis of magnetite ore is routinely used as a ore grading technique.(Zablocki,1973, Plummer,1982, Eloranta,1984) Readings are taken on one-foot intervals down the hole using a truck-mounted probe.(Fig. 5) About 20% of all blast holes are monitored. The result is a detailed ore grade profile of each bench. The data are stored in the computer where they can be attached to the blast hole coordinate file.

The attached plot shows a typical magnetic profile of a blast hole. Massive beds often show up as relatively uniform areas. Hole collars show very low values due to fluting and resulting increased distance between probe and blast hole wall.

DRILL MONITORING

Drill monitoring is the centerpiece of blast design information. The parameters that appear to most helpful are: penetration rate, depth of loose at collar, air pressure and specific energy.(Fig.6) As older drills in the fleet are replaced; monitors will eventually be on all drills. At the time of writing, only one drill has it. Drill monitoring has been extensively described by Hendricks et. al. (1992).

DOWNSTREAM FEEDBACK

Since 1988, shovel and crusher performance has been saved for blast analysis purposes. This file is based on shovel coordinates resulting from daily surveying. Estimates of size distributions are generated by a digital image analysis system located at one of the primary crushers.(Grannes, 1994) Between a quarter and a third of mined ore is sampled by this method as trains dump into the pocket. Surveyed shovel coordinates are also used to tie crusher performance to pit locations. The following parameters are recorded:

1. Shovel speed
2. Crusher speed
3. Crusher amps
4. Crusher hang-ups

CROSS HOLE SONIC LOGGING AND GEOMECHANICAL TESTING

Preliminary work on acoustical logging between adjacent holes was initiated this year. Curtailment of funding for the U. S. Bureau of Mines has put this work on hold. Laboratory samples showed a relationship between sonic velocities and compressive strength.(Fig. 7)(Jessop, 1995) It was felt that sonic logs of adjacent holes could be compared to drill monitoring parameters. This could, in effect, calibrate drill monitoring to compressive strength. One of the early benefits of this project was to discover that the oversize blocks had higher than expected compressive strength. Some samples exceeded 100,000 psi where values of 60,000 psi were expected.

CONSOLIDATION OF DATA AND OPTIMIZATION

The end product of this project will be a detailed characterization of each blast hole. The rock strength, grindability, jointing, ore grade, geologic horizon and ore grade will be available on a foot-by-foot interval. Allocation of drilling and blasting agents can then be done on a rational basis. At this point, a closed loop for optimization is formed. We will have the three phases of blasting under control:(Fig. 8)

1. Knowledge of pre-existing rock
2. Design inputs of blast
3. Output of process from downstream factors

Beginning with simple rules of thumb; computer generated designs can be refined through experience. Bulk loading trucks will soon be available to load holes according to instructions loaded on disk or transmitted by radio. Two Manufacturers offer computerized trucks that can be adapted to accept digital instructions.

The caveat to this approach is summed up in the phrase, "Increased rewards bring increased risks". As individual holes have heavier and lighter loads; flyrock or frozen zones are possible if loading instructions are transposed between holes. It will require vigilance to edit and scrutinize all designs as well as careful monitoring of column rise of blasting agents.

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Appendix

Test Procedure for 6 Minute Grind Index(Plummer,1983)

A sample is reduced to minus 20 mesh (-0.0328 inches) in preparation for liberation grind testing and magnetic tube (Davis Tube) concentration. This minus 20 mesh sample is screened for its percent minus 270 mesh (-0.0021 inches) content and recorded as "as is" percent 270 mesh. The sample is then ground for exactly 6 minutes in a laboratory ball mill. The ground product is screened for percent 270 mesh.

The mill product's percent minus 270 mesh content minus the "as is" percent 270 mesh is the amount of 270 mesh produced in the 6 minutes of grinding and is recorded as the 6 minute grindability index.

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